

Each of the annual prizes established by the will will be awarded at least once in the course of every period of five years, commencing with the year immediately following that in which the Nobel endowment enters on its functions, and the sum total of a prize thus awarded will in no case be less than 60 per cent. of the part of the yearly revenues disposable for the distribution of the prizes; neither can it be divided into more than three prizes at the most.

Immediately after the approval by the King of the statute of endowment, the corporations will designate the stipulated number of representatives, who will assemble at Stockholm and elect the members of the board of administration, who will have the management of the endowment fund at the beginning of the year 1901. The executors of the will will take appropriate measures to terminate the settlement of the succession. The first distribution of prizes for all sections will take place, if possible, in 1901. From the endowment resources will be deducted: First, a sum of 300,000 crowns (16,000*l.*) for each section—that is, 1,500,000 crowns (80,400*l.*) in all—which, with the interest commencing from January 1, 1900, will be used to cover, in proportion, the expenses of the organisation of the Nobel institutes in addition to the sum the board of administration shall judge necessary for the acquisition of a special site destined for the administration of the endowment and including a hall for its meetings.

The right of presenting proposals for prizes belongs to—

(1) Native and foreign members of the Royal Academy of Sciences. (2) Members of the Nobel committees for natural philosophy and chemistry. (3) Professors who have received the Nobel prize of the Academy of Science. (4) Ordinary and extraordinary professors of natural sciences and chemistry in the Universities of Upsala, Lund, Christiania, Copenhagen and Helsingfors, in the Carolin Institute of Medicine and Surgery, the Superior Technical Royal School, as well as to the professors of the same sciences in the Stockholm High School. (5) Incumbents of corresponding chairs of at least six universities or high-schools, which the Academy of Science will select, taking care to divide them suitably between the different countries and their universities. (6) Learned men, to whom the Academy shall judge proper to send an invitation to this effect.

The invitations will be sent every year in the month of September. Proposals for the prize must be made before February 1 of the following year. They will be classified by the Nobel committee and submitted to the college of professors. The Nobel committee will decide which of the works presented shall be submitted to a special examination. The college of professors will pronounce definitely on the distribution of the prize in the course of the month of October. The vote will be taken in secret; if necessary, the question may be decided by drawing lots.

The right to present candidates for the Nobel prize belongs to the members of the Swedish Academy, the French Academy, and the Spanish Academy, which resemble the Swedish Academy in their organisation and aim; to the members of the literary departments of other academies, as well as to the members of literary institutions and societies analogous to academies; to professors of aesthetics, of literature and of history in the universities. This order must be published at least every five years.

ELECTRICAL ENGINEERING AS A TRADE AND AS A SCIENCE.¹

I DO not intend to make this in any sense a report of the progress of our Institution during the last or any number of years. I shall not, therefore, give any account of the exceedingly good work done by Colonel Crompton and the active service corps of our Electrical Engineer Volunteers in South Africa. I shall not describe how we fitted our American cousins in England and France, or how they fitted us; nor what a wonderful success accompanied all that was attempted by us or by them or by M. Mascart and our French colleagues, although I cannot refrain from bearing my testimony to the great kindness of the Prince of Wales and the British Commission in so generously lending us the British Pavilion for our great reception, and giving us the use of one of its rooms for our office all the time of our visit to Paris.

My brother has tried to get me to introduce to your notice

¹ Inaugural Address, delivered at the Institution of Electrical Engineers on November 3, by Prof. John Perry, F.R.S., President.

some novel ideas which have come to us during the last ten years in our business of lighting the city of Galway from a fairly constant water-power, using accumulators with a gas plant stand-by. It has almost come to be a practical idea to produce carbide of calcium in wet seasons and utilise it through the gas engine in dry seasons. I was also tempted to discuss the use of large gas engine plant at central stations; and another of several subjects in which I have been recently engaged has been the magnetic effect produced by systems of electric traction. But I have resisted temptation and have chosen a subject which seems to me much more important.

Your president's address is followed by no discussion. He is, therefore, privileged, but his very privileges cause him to address you with a greater sense of responsibility; he may say what he pleases, but he must be very sure that he has the best interests of the Institution at heart; the interests of the Institution as a whole, not the interests merely of a few members, and least of all ought he to think of his own interests. Nevertheless, your president speaks not as an omniscient judge, but rather as a very fallible, very prejudiced, one-sided man who, because he has devoted himself to one part of the work of this Institution, is certain to be unfair in his comments upon other parts of the work.

Your past presidents represent in this way all classes of members of this Institution. You have had scientific men, given some of them to calculation and some to experiment, and some to both; men who have advanced the study of pure science. You have had practical telegraph men, civil and military; men cunning in land and deep-sea telegraphy and telephony; men cunning in railway signalling. You have had electrical chemists. You have had manufacturers and users of all kinds of electrical appliances. You have had men who devote themselves to the teaching of electrical engineers, and who fully appreciate the fact that no good teacher ought to be out of practical touch with the profession. And nearly all of your past presidents have invented things which are now in practical use.

As each of these men has given you at least one address written from his own peculiar point of view, his prejudices are not likely to have done any harm to members who read the other addresses. I know, therefore, that you are good-naturedly prepared to give me plenty of rope. I can predict the twinkle of amusement in the faces of some of my friends when they learn that I am about to take up a subject on which we have had many debates.

In this address I mean to put before you this simple question: Is electrical engineering to remain a profession or is it to become a trade? Is this Institution to continue to be a society for the advancement of knowledge in the applications of scientific principles to electrical industries, or is it to become a mere trades union?

Of course, at the present time the outside public are willing to regard membership of this Institution as a symbol of something more than the membership of a mere trades union. During the early growth of any trade, even such a trade as that of the plumber, it was really a profession. And a common trade may suddenly become a profession, if it suddenly begins to develop, as, for example, stone-masonry of a hundred years ago suddenly developed into civil engineering. Electrical engineering has been developed rapidly, so that in the past it has certainly been a profession and not a trade.

Again, we are an institution of engineers, and the general public are willing to class us with other engineering institutions—for example, the Institution of Civil Engineers. Now the title M. Inst. C. E. is a professional distinction which represents in civil engineering what F. R. C. S. does in surgery, or M. R. C. P. in medicine. We owe a great deal to our association with, and recognition by, the Institution of Civil Engineers; our meetings are held in its rooms; many of our members are also its members; our proceedings are modelled on its proceedings.

Now this older Institution, governed by the best thoughts of the best British engineers, has laid it down that its associate members, that important class from which the higher class is mainly fed, shall have passed certain specified examinations in pure and applied science. I am not now suggesting that we ought to adopt this science examination method of admitting any kind of members to our Institution. I do not believe in the wholesale adoption of methods of working from another society. I am asking you early in my address to remember that this greatest of all professional engineering institutions, governed by practical men full of common sense, knowing the wants of their

profession well, insists upon a knowledge of science in its new members. If this recognition of science did not exist anywhere else in the whole world, I say that its recognition by such a thoroughly good professional society as that of the Civil Engineers ought to recommend it to all professional societies.

In Germany an enormous stride has recently been made in the raising of Engineering degrees to rank with the highest University honours. There is hardly one engineer of eminence in Switzerland, France or Germany who has not passed with honour through the classes of one of their great science Universities.¹ In Great Britain, within the last fifteen years, not only have great engineering schools been established in all the manufacturing towns, but even in Cambridge University there is one of the best schools of civil, mechanical and electrical engineering of which I know anything.

Before we think of imitating the Institution of Civil Engineers, we ought to reflect on certain fundamental distinctions between that Institution and our own, which at first sight seem to make us less professional.

There is a well-known unwritten rule of the Civil Engineers, to which there are only a few exceptions, that no contracting railway or harbour engineer can acquire the title of M. Inst. C. E. I think myself that it is a pity to draw a hard and fast line between consulting engineers and contractors. No doubt it simplifies the labour of the Council in its selection of candidates, but it gives rise to anomalies.

A man, who was once a civil engineer because he served a pupillage under his clever father, and who now is nominally at the head of his father's large practice, the real engineering work being done by many clever employees, this man may be a member. A contracting engineer who shows marvellous ability, not only in rectifying the mistakes of the designer of a large bridge or tunnel or reservoir embankment, but shows the power of Lord Kitchener in directing the work of thousands of men, so that no man need be idle, and the whole contract goes on like clockwork, and is finished well in the minimum of time, this man is ineligible. Now, in our institution, it has been recognised from the very first that manufacturers and contractors and their employees may belong to the very highest ranks of their profession. Of course, I do not mean men who simply receive the profits of businesses, or even men who merely work to obtain orders for themselves. I mean men who are not merely formally, but in reality manufacturing or contracting engineers. I mean men who, in dealing with standardised things, design new methods for quick, good, cheap production of such things. I mean men who improve old forms of things, possibly through their paid subordinates. I mean by a manufacturer fit to be a M. I. E. E., a man who might act as his own manager, and who, perhaps, has a wider outlook than on mere managerial duties. So long as a contractor or manufacturer is really an engineer, we know that we add to our strength with the addition of every such member.

But consider a contractor who only uses ordinary types of machines or electrical plant in well-known ways, surely he can hardly be said to be in the profession at all. Surely the one thing that differentiates us from mere tradesmen is that we do not follow mere rule of thumb methods; we think for ourselves, we weigh advantages and disadvantages. If every new installation required the same treatment as existing ones, the engineer would degenerate into a tradesman, and it seems to me that the electrical engineer ought to have a special fear of such degeneration.

In railway and harbour and river and sanitary engineering, in every new job, there are new difficulties to be dealt with. An engineer who designs many undertakings and sees them carried out must be a thoughtful man; he cannot help keeping himself acquainted with engineering principles, and so he is a professional man. So an architect finds that each new job requires all his experience. Every case that comes before a real physician or surgeon requires a somewhat different treatment from any old case. Every case brought before a barrister requires the exercise of all his past experience. In every case a *profession* implies the necessity for the exercise of all one's past experience; because the work one has to do is never the same as any work

¹ I understand also that the great unions of manufacturers in Germany are about to make facilities for giving a year of real factory work to the Polytechnic students, thus perfecting the German system. In Japan we found great success in requiring students to spend their summer in real shops, their winters at college. In England it may be that we shall prefer to let apprentices have shorter factory hours than workmen, their masters being responsible for instruction being given in theory.

one has ever done before. And when I say past experience, I really mean certain general principles which one has always in one's mind, principles derived from all that one has done or seen or read about.

Electrical engineering is in a curious position. It owes its being altogether to scientific men, to the laboratory and desk-work of a long line of experimenters and philosophers. Even now the work going on in a laboratory to-day becomes the much larger work of the engineer to-morrow. When at length the laboratory experiment is utilised in engineering, we see that there is no other kind of engineering which so lends itself to mathematical treatment and exact measurement. Most of the phenomena dealt with by the electrical engineer lend themselves to exact mathematical calculation, and after calculations are made exact measurements may be made to test the accuracy of our theory. For a completed machine or any of its parts can be submitted to the most searching electrical and magnetic tests, since these tests, unlike those applied by the mechanical engineer, do not destroy the body tested.

Contrast this with the calculations it is possible to make in other kinds of engineering. The pressure of earth against a revetement wall is possibly 200 or 300 per cent. greater, or 50 to 70 per cent. less than what we imagine it to be in what some limited men call theory. We use factors of safety 5 or 10 or more on all kinds of iron structure calculations, because we are aware of our ignorance of a correct method of dealing with the problems. The civil engineer never has exactly the same problem as has already been solved. In tunnelling, earthwork, building, &c., in making railways and canals, he is supremely dependent on the natural conditions provided for him; the configuration of the surface of the ground, the geological formation, the structural materials available in the neighbourhood. The story of how the engineer has to study the endlessly different ways of interaction of water and sand and gravel is told by the troublesome bars at the mouths of rivers all over the world, by the difficulties of coast and river-bank protection, by the failure of sea walls and piers. But why should I make a catalogue of the different kinds of work done by civil engineers? Every one of them needs the exercise of general scientific principles due to much experience.

Now of all such natural difficulties the consulting or contracting electrical engineer is greatly independent. Give him a source of power, and tell him what is to be done; whether he is to light a town or a building, whether with arc or incandescent lights; whether he drives a stamp mill near a mine or a pump, or a machine tool, or a spinning frame; the electrical part of the work is carried out in much the same way. Natural conditions affect him mainly in the cost of transport of his materials and the cost of labour. He can make in an easy way the most careful calculations as to the best arrangement of his conductors and machines to give maximum economy, and except for this easy calculation his work is that of a mere tradesman. He is practically independent even of the weather. There are, indeed, some of us who grumble that this easy calculation is not made easier still, who prefer to make arithmetical guesses rather than exact calculation, because perhaps we like to see a little uncertainty introduced into the problem to make it more like a problem in civil engineering. I want members to see clearly that as times go on, as our electrical engineering work gets more and more cut and dried, the man who loses the power to calculate, who loses his grip of the simple theory underlying our work, must sink more and more into the position of a mere tradesman who has no longer the right to call himself an engineer.

An electrical engineer must have such a good mental grasp of the general scientific principles underlying his work that he is able to improve existing things and ways of using these things. It has become the custom to call this *theory*, and I suppose I must follow the custom. I should prefer to call it *Science*¹ or *knowledge*. Do you remember Huxley's definition of Science? "Science," he said, "is organised common sense"; and this is really what I mean. Well, calling it *theory*, the man who is

¹ What Falstaff said of the word "occupy" we have to say of the word "Science." It is used by many people out of its proper meaning and then condemned, so that one is getting afraid to use it. In Prof. Fitzgerald's splendid inaugural address to the Dublin Section of this Institution he says: "As has recently been pointed out to me by Dr. Trouton, it would be impossible to say the same contemptuous things of *knowledge* as are said of *Science*. In Germany the word used, 'Wissenschaft,' is the one corresponding to our word 'knowledge,' and there nobody of any sense could say that 'knowledge is all humbug,' as is here often said, and still oftener thought, of 'Science.'"

permeated by theory, whose theory is so much a part of his mental machinery that it is always ready for practical application to any problem, he is the real engineer. But you must not mistake me in this matter. Eighty per cent. of the men who pass examinations in mathematics, mechanics and electricity have very little of this theory. Fifty per cent. of the writers of letters in the engineering journals in which mathematical expressions occur have almost nothing of this theory in their possession. It is unknown to foolish men. Books alone, lectures alone, experiments alone, workshop experience alone cannot teach this theory. The acumen of a Q.C. may actually prevent a man from acquiring it. A man may have much of this theory, although he may never have listened to lectures, although he may dislike the sight of a mathematical expression. I have known men who might be called illiterate to possess much theory. I have known many men who might be called good *electricians* who are almost wanting in the theory necessary for the electrical engineer.

I am speaking only of theory. Of the other qualifications for an engineer I need not here speak; they are present to the minds of all of us. A man may have any amount of knowledge; he may know how to apply his knowledge, and yet he may not be able to apply the knowledge from a want of engineering character.

The engineer must be a real man; he must possess individuality, the power to think for himself. He must not be like sheep, knowing only enough to follow the bell-wether. Over and over again in the last thirty years have some of us given our students much the same sort of advice that Baden-Powell gives to scouts in that excellent little book of his. If any of you have not read that book you ought to buy it at once, and you will there find that if a man is to think for himself he must possess all kinds of knowledge, he must be constantly picking up new kinds of knowledge.

Nobody can limit the value of any kind of knowledge, but still one may say that certain things are probably more important than others. To gain what we call "theory" a good general education is most helpful—mathematical knowledge is very helpful; laboratory and workshop experience are extremely helpful. There is one qualification which the electrical engineer must have and without which all other qualifications are useless, and if a man has it no other qualification is supremely important, and this absolutely indispensable qualification is that a man shall love to think about and work with electrical things. He must like these, not because of the money he can make through electrical contrivances, nor even, I think, because of the name he may make before the world—this would be mere liking or cupboard love which has no lasting quality. So long as we have men in this country who have the true love for scientific work of which I speak, so long shall we have a real profession of electrical engineering, for such men are always scheming new contrivances and improving old ones and utilising the services of all helpful people, and especially of capitalists. When we have reached a state in which nobody schemes new things because the existing things are perfect there will no longer be a profession of electrical engineering. Of all ideas surely that of having reached *perfection* is most hateful: the idea of exact knowledge, that nothing is unknown, that there is no need for thought and therefore that to think for oneself is a sin.

And so, although we are all agreed that much standardisation in our contrivances and methods is absolutely necessary for our competition with other nations, we must follow the Americans in this matter and take care that it does not destroy invention. Of course when things are really standardised, when we have our perfect Mauser rifle or dynamo or locomotive or traction engine or electrically driven stamp mill, a Boer can buy or even manufacture them if he has money, and he can use them as well as, or possibly better than, we can. But he is not an engineer. He uses things after the engineer has done his work upon them. A stoker, a common engine-driver, the guard of a train, these are not engineers. You must have noticed that the American engineers, who surely deserve the character of being practical idealists above all other engineers, are the men who are most imbued with notions of standardisation which lead to cheapness of manufacture, and they are also the men most alive to the necessity for occasional scrapping of types of machinery when they become even a little antiquated.

Our chiefs, the men who run us all, our real men at this Institution, may be called Practical Idealists. They have imagina-

tion and judgment and individuality. They have the imagination and enthusiasm of inventors, and yet they are more than inventors, for they can estimate the worth of their own inventions and control their imaginations. They are ready to receive all new things, and yet they are not carried away. They are radicals and yet they are conservatives. They have what Mrs. Beecher Stowe called *Faculty*.

A strong imagination well under control, surely it is the greatest of mental gifts. I look round me and wonder how many of us really have it; and how many of us are only dull music-hall loving men, who scorn novels and poetry, who live utilitarian, material lives, whose aim is merely to make money through electricity, who love it not for its own self, who cherish their "tuppenny-ha'penny-worth" of theory because it is sufficient for their immediate wants. Why, even the writers of leading articles in the daily papers can talk of the wonders of electricity and what may yet come to pass; and yet we who make machines and use them and switch the marvellous thing on and off and take all sorts of liberties with it—we are like Calibans oblivious of the wonders of the fairy isle—like soulless priests making a living in the temple of Isis—like Aladdins who rub our lamp only to get the necessities of life.

Twenty years ago some of us were laughed at for our optimism, and yet everything that we declared then to be doable has now actually been done by engineers, except the thing which was then and is now declared to be the supremely important thing, namely, the electric consumption of coal. We say now, as we said then, "The applied science of the future lies invisible and small in the operations of the men who work at pure chemistry and physics." And think of the wonderfully rapid rate at which laboratory discoveries have been made in the last eleven years, and how as the years go on they become more and more numerous; and yet many of us plod along with our work seeing no farther than our noses. A year is now more pregnant with discovery than a hundred years used to be, and yet the protective solidity of our ancestors is upon us and we think of the latest discovery as if it were really the very last that can be made. A thousand men are measuring and trying new things in laboratories all over the world. Some of them plodding and soulless; others of them with imagination and clearness of vision. Do you think that nothing is to come from all that work?

And is it not one of the most important functions of the engineer to do as Mr. Marconi has done, to convince capitalists ignorant of science that if the successful laboratory experiment is tried on the large scale, it must also be successful? And are we going to leave all this pioneering work, with all its possibilities of great gain, albeit with possible loss, to foreign engineers, when in most cases the scientific discovery has been made in England? Are we so lacking in the hope and faith which are born of imagination and science? And must we in the future, as in the past, have to rely upon the influx of the clever foreigner like Sir William Siemens? Must we, Boer-like, always depend upon our Uitlander population, Fleming and German, Hollander, Huguenot and Hebrew, for the development of our natural resources?

Some of the best engineers I know are so exceptional that one must class them with geniuses; they have faculty and character, and so they have become engineers, even under the most unfavourable circumstances. They have passed through ordinary schools and yet developed common sense. They were pitchforked into practical work, and their liking for the work, as well as some curious kind of instinct, led them to pick up all sorts of knowledge, which have become part of their mental machinery. They continue to pick up new kinds of knowledge when these become necessary for their professional work. Unfortunately, these men do not realise how exceptional they are, and they advise boys to go direct from school into works. They forget that the other 99 per cent. of men treated in the same way as themselves can only become the hewers of wood and drawers of water to real engineers. Treated in this way, average boys are just like so many sheep: they learn just what seems absolutely necessary and no more; their acquaintance with the scientific principles underlying their trade is a hand-to-mouth knowledge, which becomes useless when their trade undergoes development.

In 1867 I was an apprentice, and when in the drawing office and pattern shop I remember well how I was chaffed for studying such a non-paying, non-practical subject as electricity. When I published my first electrical paper in 1874 before the

Royal Society, and even for some years afterwards, the real students of electricity in England could be counted on the fingers of one's hands. Many of us remember the first gramme magneto machine that came to this country, a scientific toy, in 1874. How many engineers dreamt that a great new branch of engineering had been started? Even in 1878 engineers were as a rule quite ignorant of electricity, and since then every year, although newspaper writers have talked largely of the age of electricity, the men actually engaged in electrical industries have acted as if the greatest of changes were not perpetually going on in it. To be left behind, or to become camp followers, children of Gibeon, this is the usual fate of the men who scorn theory. In 1882-4 we used to have to pay men 200/- and 300/- a year because they had a slight knowledge of electrical matters. In 1884-6 these very men were not worth twenty shillings a week; they were weeded out of the profession, and their places were taken by men of better knowledge. Two or three years after, these better men were again found to have been weeded out, because men of still better knowledge were available. And so it has gone on ever since. Men learn just enough to get posts; they settle down in these posts and scorn theory. They actually forget what little theory they once did possess. They know a great deal about existing machines, but presently they discover that improvements have been going on, and that they no longer have a right to say that they belong to the engineering profession. In every year one has told men, "You will be left behind. See A and B and C. I told them three years ago, when their names were in everybody's mouths, that they would be left behind like their predecessors, and they laughed. Now I tell you and you laugh, and you also will be left behind. Yes, I know that you get a good salary or large fees, and your head touches the sky. Nevertheless, because you neglect theory and the simple mathematics, by means of which theory is made available in practical problems, you will have to take a back seat presently, for our profession is in its early youth and is growing rapidly."

Remember that I do not now refer to the few exceptional heaven-born engineers who, in spite of bad training, do manage somehow to pick up the necessary knowledge. I speak of the average men, many of whom are now living in the same old fool's paradise. They know enough for present needs; they scorn the simple principles which underlie all our work; they scorn the easy mathematics by which these principles are most readily employed in practical problems; they will have their reward.

Just think of what is occurring at the present time. In England we have cheap coal, and it can be carried easily. In Switzerland and other countries where there is no cheap coal the water-power had to be utilised and power had to be transmitted great distances electrically. This needed high voltage, and as it is difficult to get high voltage with direct current machines, alternating currents were used, and on account of motor troubles multiphase working has been introduced. What a revelation it was to almost all of us, that visit of a year ago to Switzerland! We saw enormous schemes of lighting and traction and power. We saw electric trains driven by distant waterfalls sandwiched in among ordinary trains keeping proper time on working railways. We had known that there were great schemes carried out in Germany and America and other countries, and yet all the machines were quite unfamiliar to us. We were very much like what engineers of 1870 would have been if suddenly brought into a generating station. Is it not a fact that some of us, said to be eminent and thought to be practical, asked questions and made remarks which showed that we did not know the most elementary principles of three-phase working. Is it then any wonder that the traction schemes now being developed in England, on lines that are certainly not the best for this country of their adoption, are altogether dependent on the use of foreign electrical machinery and employ foreign electrical engineers? I am not putting this altogether fairly, for municipal procrastination has prevented our development, and yet I am not putting it altogether unfairly. We know too little theory.

I am afraid that just now we are in a rather tight place. I would give something to know how we in this room are going to get acquainted with modern electrical engineering. Our usual way of learning is by actual handling of things. But if the millions of pounds' worth of machinery coming to England every year is all foreign, and is used mainly under foreign superintendence, our usual method of study is made very difficult.

True, there are American and German, and, indeed, English publications which would give a knowledge of the theory, but not, I think, to the average English electrical engineer. I know of many men, twenty-five to forty years of age, who seldom come to our meetings, and who say they are silent in discussions because they cannot be understood; perhaps these men will find a way to save us all from being left behind. There is much more that I might say in this connection. An individual Englishman may be left behind other Englishmen, and all English electrical engineers may be left behind the rest of the world, but all electrical engineers of the world may even be left behind other appliers of science. It is not merely that the incandescent mantle of the gas engineer is improving and necessitates improvements in our filaments, but, in spite of the flourishing conditions of our factories just now, I could give many other illustrations of how we shall all suffer if we do not keep adding to our knowledge. Twenty years ago, when giving some lectures in Clerkenwell to workers in the then flourishing watch trade, I ventured to prophesy the decay of that trade. But I am afraid that the case of Jonah and Nineveh is the only one in which prediction of disaster led to reform. I venture on no prophecy, therefore, because it might harden your hearts.

Much of the evil we suffer from is due to our average young men being pitchforked into works where they get no instruction, as soon as they leave school. If ordinary school education were worth the name, and if schoolmasters could be brought to see that we do not live in the fifteenth century, if boys were really taught to think for themselves through common-sense training in natural science, things would not be so bad. But the average boy leaves an English school with no power to think for himself, and with less than no knowledge of natural science; and he learns what he calls mathematics in such a fashion that he hates the sight of a mathematical expression all his life after.

And what is the result? English engineers do make a wonderfully intimate acquaintance with the machines and tools that they work with, but when it comes to the manufacture of new things they do it by fitting and trying, by quite unnecessary expenditure of money through trial and error. A machine is made and tried, and then another better one, until a good result is arrived at. And this method did well enough in the past, and would do well enough in the future if only we had not to compete with foreigners who can really calculate. It is not all smoke; there is a real danger in this foreign competition unless we mend our ways. There is an absolute necessity for great change in English ways; but there are so many people interested in the maintenance of old methods of working; so many people who think they will lose their bread and butter if a change takes place; so much capital, scholastic and other, invested in our old machinery, that it takes a catastrophe to produce changes. Much of the strength and weakness of England has always lain in her conservatism. We have been talking of standardisation of machinery lately, so I may say that things have been standardised in England for a long time. Now to get all the good effect of standardisation, it is occasionally necessary to go in for wholesale scrapping, and it is this scrapping part of the business that we dislike in England. We here all know that the District and Metropolitan Railways might have been worked electrically years ago just as easily as they will be when we are allowed to begin upon them, but of course the scrapping of a lot of steam locomotives was a serious thing. The loss of experience to English electrical engineers, because of this hatred of scrapping, is leading to other incalculable losses. I understand that the whole generating and line plant—the whole machinery of the Boston tramways—has been scrapped several times since they first were driven electrically. Japan has scrapped all her old civilisation just as France did. During the century now dying Germany has made the most sweeping changes in her law and school legislation, and indeed in everything. England and Spain and China, how they differ in this respect, even from England's own colonies.

Of course it may be said that English customs have grown during centuries; they are well tried, and there is no pressing need for sudden alteration. I quite agree, but unfortunately this very perfection and fitness of our customs have bred in us a want of flexibility, so that in cases where a sudden change is really necessary, we are disinclined to make the change merely because it is a change and for no other reason.

No one has ever heard me speak of the decadence of England. When the greatness and the wealth, the manliness and the strength, the healthiness and good life of England are shown

forth to the as yet ignorant world in all their magnitude there will be some astonishment. But it is our duty to keep up our high standards. We must change what is bad when we know it to be bad, and not let bad things¹ continue to exist, parasitic growths, maintained because on the whole we are strong and healthy. You will perhaps think that this is a very serious exordium when I tell you that I have introduced it all on account of the state of mathematics in our profession. I feel a sort of degradation every time that I hear a successful, clever old member of this Institution sneering at mathematics. There is a plausibility about his statements; he himself has been very successful in life without much help from mathematics; but indeed his sneer is doing a great deal of harm to the younger members who admire his success, who forget that he has succeeded in spite of, and not because of, his neglect of mathematics.

Our knowledge of electrical phenomena must be quantitative to be of practical use; we must be able to calculate. Mathematics is the science of calculation, and we must therefore be able to employ, and we all do necessarily employ, less or more mathematics every hour of our professional lives. The draper and the grocer and the housekeeper merely need arithmetic. Everybody now knows some arithmetic. Everybody can add and subtract and multiply and divide, and keep accounts in some simple sort of way. This is due to the fact that arithmetic is no longer taught in the old Greek method with its twenty-seven independent characters (for our ten figures), the study of which required a lifetime, so that only old men could do multiplication, and they not only needed many hours to do one easy bit of multiplication, but declared that if the art were not practised every day it could not be remembered. Reading and writing and ciphering are now taught to everybody. It used to be that only learned men and philosophers could read, write and compute. You will remember the charge that was brought against one of Shakespeare's characters, who was said to possess mere bookish theory without practical knowledge. "And what was he?" "Forsooth a great arithmetician." Nowadays, when everybody can compute, we should say of the possessor of mere bookish theory, "Forsooth he knows the calculus."

For in mediæval times things were taught in such a way that only a few men had a chance of knowing how to read, write and cipher. We have been compelled to change all that; the pedagogue has, by compulsion, given up his mediæval methods of teaching in these things, although in all other matters he retains them. But a time has come when we see that ciphering is not enough mathematics for us to be familiar with, we need a little algebra, we need co-ordinate geometry, we need the differential and integral calculus. The pedagogue tells us that we must follow the orthodox course of study, which takes many years; and some of us, many of us, who have followed the orthodox method, find that we have spent so much time and mental power upon it and its thousands of unnecessary tricks and contrivances and philosophy, that we can take in no more ideas. We cannot utilise our mathematics on engineering problems because we are too old and tired and *blasé* to comprehend these problems. Nevertheless we are the only people who know mathematics, and so we publish volumes of unmeaning and useless disquisitions on problems that we do not understand. Or we know just enough mathematics to be able to show our ignorance to experts, but quite enough to impress engineers with our knowledge; and we know just enough about engineering problems to show our ignorance to engineers, but quite enough to impress mathematicians, and what we publish is merely as the crackling of thorns under a pot.

As for the man who does understand electrical problems, he remembers that there was a something called a study of mathematics at his school, that he did pass certain examinations with much difficulty and tribulation, that the subject had no real meaning to him even when he was supposed to know it, and he now hates the sight of anything that looks like mathematics.

I tell you, gentlemen, that there is only one remedy for this sort of thing. Just as the antiquated method of studying arithmetic has been given up, so the antiquated method of

¹ Such as our wretched system of weights and measures. Oh, young America and Australia, is it wise to waste a year of every child's life, and years of the life of every business man, merely because we do it in England? You get many of your pedagogues from us, and of course they say that without cwt., qrs., lbs., and Latin declensions and Euclid, the mind cannot be trained. Do you believe them, or are you with open eyes making a great sentimental sacrifice?

studying other parts of mathematics must be given up. The practical engineer needs to use squared paper. What is the use of telling him that he has taken an unauthorised way to the study of co-ordinate geometry, that he cannot approach it except through Euclid and modern geometry and geometrical conics and algebra and trigonometry? He says the youngest child can be made to understand diagrams on squared paper.

So again the idea underlying the calculus is one that every child, every boy, every man possesses and uses every day of his life, and there are useful methods of the calculus that might be taught quite quickly to boys, and which it would be a pleasure to boys and men to use continually in all sorts of practical problems; but of course the subject of the differential and integral calculus is one that must come at the end of a long course of what is to the average boy utterly uninteresting and unmeaning mathematics. Indeed, the average boy never reaches the subject, whose very names, differential and integral calculus, are enough to drive him frantic.

Yes, the schoolmasters say that we must follow the mediæval rules of the game, and all sorts of fine things are said about them; but as a matter of fact we only need to bring a little common sense to bear upon schoolmasters. At present most of us stick to our arithmetic as a safe and well-tried friend. We compute after the manner of the draper and grocer and house-keeper. In finding out what is the best size of conductor, or armature winding or core, or iron and winding of a field magnet, we calculate by mere arithmetic for one size and then for another; perhaps we have weeks of arithmetical computation before we find the right size of thing to use, and we cannot frame general rules. And some foolish person who knows a little mathematics, works at the problem (as we ought to be able to do, but are not), and he frames a general rule and we laugh at it, and sneer at mathematics because he has probably left out of account the most important consideration. We know that the result is wrong, but we cannot say why it is wrong.

Then there are some far-reaching, labour-saving ideas that we simply cannot get into our heads at all; we cannot comprehend them. Am I sinning against the rule as to good comradeship which exists here if I say that some of us are ignorant of the most fundamental facts regulating economy in arranging sizes of conductors? Suppose we find the total cost of installing a conductor of a certain length, using one square inch section of copper. We do the same thing for other sizes, and we plot total cost and weight of mere copper on squared paper. I do not care what system we adopt if it is the same system for all sizes, and if we buy our materials from the same manufacturers and use the same kind of labour, our points will lie very nearly in a straight line on the squared paper. Hence increased cost will be proportioned to increased weight of copper, and, indeed, increased total cost will be like the mere increase in the cost of copper, taking a slightly higher price of copper per ton. Some of us, ignorant of the elementary mathematics involved in the problem, think that the mistake has been made of assuming that the cost of an installed conductor is merely the cost of the copper in it, and, of course, he must feel that it is too absurd a mistake not to be laughed over. With an elementary knowledge of mathematics his mistake would be impossible, and without such a knowledge the clever electrical engineer is constantly discovering mares' nests in the investigations which he criticises.

I know of long misleading accounts of the results of good experimental observations which might have been described in a few clear words by the aid of elementary mathematics. I know men who spend on a particular problem ten times the amount of worrying thought that would enable them to master the easy mathematics that includes all such problems. Quite recently one of our most eminent members declared to me that he had not really grasped the reason for small economy at a power station when there is a small load factor until he studied the common-sense mathematical form which has been given in a recent publication. And yet he is a man who has heard much, and read much, and talked much on this subject.

Every electrical engineer has a correct idea of how a transformer acts, or how the E.M.F. in one of the coils of an armature of a direct current or other generator, or, let us say, a rotary transformer, changes during a revolution, and how the E.M.F.'s of all the coils are combined to produce currents in the external circuits. But through how much mathematical tribulation must most of us have passed from our state of ignorance to our present state of knowledge! It is no wonder that we are disinclined to the study of a new phenomenon which seems as if it

might lead us through the like tribulation. The tribulation is least because it is suffered only once if we first learn the calculus method which underlies all our work; it is greatest if we get it up in a completely new-looking form in every new problem. I speak now of what is most difficult in our study, for there is thought required in applying the calculus method. Thus, for example, in multiphase work at the present time the best mathematicians wonder how it is possible for easy calculation to be made in such a subject. What we want just now is that an electrical engineer acquainted with three-phase current phenomena should be so much a master of ordinary easy mathematics that he has a chance of discovering a very simple way of putting the matter before us. At present calculation is easy but tedious, and, indeed, repellent; but I am perfectly certain that a competent man might quickly invent methods of calculation which are not only easy but short and thinkable. Mathematicians with the requisite electrical knowledge, again, may be lacking in sympathy and humour. I know a book of more than three hundred large pages on ordinary alternating currents, and all the information in it is given far more simply in two pages of another book with which some of you are acquainted. Possibly, just now, mathematicians who are electrical and who have common sense have too much other work to do, and we must wait their leisure.

The fact is, mathematics ought to be the natural language of the electrical engineer, and at present it is a foreign language; we cannot read or write or think in it. We are at the beginning of our development, like monkeys whose necessities have increased faster than their powers of speech.

Some of you are aware that a new method of teaching mathematics has recently been introduced in nearly all evening classes in science schools throughout the country.¹ I wish I could say that there was a prospect of its being introduced in all schools, for it seems to me that this would lead to the result that all young men entering works would be masters of that kind of calculation which is most important in electrical engineering; not merely a few men having this power, but the average men, just as average men can read and write.

I am addressing engineers, men who utilise the results arrived at by scientific workers, men whose profession is applied science. But surely if we are to apply the results arrived at by scientific men, if the laboratory experiment of to-day is the engineering achievement of to-morrow, we ought to be very much alive to all that is going on in the scientific world.

All men ought to be far more alive to the importance of scientific work. On the psychological side, it is perfectly exasperating to me to see how few are the men who know that Darwin has given a key to almost all the great philosophical problems of antiquity, and that there is a great mental development accompanying the more evident engineering development now going on in the world. Again, it is the fault of our methods of education that all our great men, our most important, most brilliant, best educated men; our poets and novelists, our legislators and lawyers, our soldiers and sailors, our great manufacturers and merchants, our clergymen and schoolmasters, should remain so ignorant of physical science, the application of which by a few men not ignorant is transforming all the conditions of civilisation.² But, of all men, just think what it means for engineers to be ignorant of science, or neglectful of its new developments; and, of all engineers, think what it would mean if electrical engineers sinned in this way.

Except ours, all other branches of industry have taken thousands of years to grow. There were bridge and hydraulic and sanitary and harbour and river engineers in ancient Rome, and such engineers existed thousands of years before the first papyrus was written in Egypt. But no Assyrian tile or Egyptian hieroglyphic or relic from a tomb indicates that telephones or electrical motors or electric lights existed before our time. No gradual improvement in our methods of conquering nature led up from small beginnings in our electrical engineering. Our profession has not grown during thousands of years of time, like other professions. It has sprung suddenly, full grown, from the new spirit which is going to rule the souls and bodies of men, the spirit of research in pure

¹ See summary of Lectures on Practical Mathematics; also the Science and Art Directory, and the Reports of Examiners on the Science Examinations of 1899 and 1900, all published by the Education Department, South Kensington, S.W. The reforms now advocated in mathematical and science teaching are all clearly described in a paper read before the Society of Arts in January, 1880.

² See articles in NATURE of July 5 and August 2.

science. The new spirit puts knowledge, mere knowledge of nature, as its highest aim. The scientific student knows that all sorts of good must come to mankind from his studies; all sorts of scientific knowledge are sure to be utilised by engineers, but in the pursuit of science the usefulness and utility of the results are of no importance. And are we—we who have received the first-fruits of the labours of scientific men, we the first-born spoilt children of the great parent of all that is to come, we who form the foremost files of the present time—are we going to turn upon our beautiful young mother and say she is useless and ugly, and she hinders our money-making, and that we are willing to kill her for the sake of the burial fee? Thank God that is the spirit of only a few of us. Have we not as an Institution gone to great expense in the publication of *Science Abstracts* in partnership with the Physical Society? That publication has been and continues to be of the very greatest value to all students of pure and applied science who read our language, for it tells them the results of all the scientific work now being done in all parts of the world. And even if some of us do not read that useful publication, do we not know that it is there to read if we like? Do we not know that it is a symbol of our redemption from the yoke of the Philistine? It is one of many signs that in answer to the question which I have asked in this address, we can truthfully say that we are professional men, that our profession has promise of enormous expansion and improvement, and that we are not mere tradesmen.

I am afraid that you will think that I have a personal interest in putting before you the claims for consideration of the pursuit of pure science, because you know that I am trying to defend Kew Observatory from imminent danger. In truth I have no interest in this matter unbecoming a president of this Institution. For two years I have been trying to reason with traction engineers. Like many other electrical engineers these gentlemen desire to use uninsulated return conductors. If they do so near a magnetic observatory certain records of terrestrial magnetic disturbances are quite spoilt. At Potsdam this sacrifice has been forbidden. At Washington, Toronto, Capetown, and most other important places, the magnetic records have already been rendered useless. Professor Rücke and I were asked by the other members of the Committee of the Royal Society which was in charge of the Kew Observatory to defend Kew, and with the help of Her Majesty's Treasury we thought we were able to insist upon the use of insulated returns in all undertakings authorised by Parliament where harm was likely to be inflicted on Government observatories. I may say that the scheme designed by Mr. Clifton Robinson for using an insulated return conductor in the working of the tramways of the London United Tramways Company, in consequence of our action, was a thoroughly good scheme which it gave one satisfaction to look at, not ugly and not expensive. It seemed to me a fit scheme for any tramway system, however complex, in which overhead conductors are used. You are aware that for an electric railway or for a tramway where a conduit is employed, it is in every way better, and is in a large scheme actually cheaper, to use an insulated return. We felt therefore very happy, for magnetic observatories seemed quite safe from interference. We were, however, mistaken, for the only clause which we have been able to get inserted in all Parliamentary authorisations of undertakings leaves it to the Board of Trade to substitute other methods of protection than the insulation of the return conductors in cases where these other methods seem to be sufficiently good for the protection of laboratories and observatories, and this is why the Board of Trade appointed the Committee which met on October 31 probably for the last time.

Prof. Rücke, Prof. Ayrton, and I have made many tests on the magnetic disturbances produced by tramways and railways, particularly by the Stockton tramways and by the Waterloo and City Railway, and we have had many meetings with the traction engineers, but nothing has yet been decided.

I mention this matter, which has given great anxiety to scientific men, because I am afraid that some of you may think when you hear of it that I have been acting against the interests of the electrical industry. I beg to assure you that I have been acting in your best interests. As an electrical engineer I ought surely to regret the use of uninsulated returns, even if we leave Kew Observatory out of account. Suppose we do not now insulate our returns. Electricity will certainly return by gas and water pipes, and

the amount of harm done to those pipes is merely a question of time. Because of the ignorance of legislators and gas and water companies, nothing is said just now; but will nothing be said at the end of ten or twenty years, when pipes are found to be eaten away everywhere? And if by a slight increase of expense, or rather, as I think, actually no increase of expense, but merely a little increase in inventiveness and common sense on the part of electrical engineers, this evil may be entirely prevented, surely it is in the interests of all of us that insulated returns should be insisted upon. But even if we do not insist on insulating the returns in all systems, surely something may be said for the giving of this protection on lines near such a magnetic observatory as Kew. Even the magnetograph records now being made have been continuous for forty-five years, and if Kew is interfered with no sum of money can compensate for the interference; for if the Observatory were removed the future observations would have no link with the past.

An engineer in this room declared that it seemed to him an injustice to hamper the progress of electric tramways "for the sake of making observations that never have given, and never may give, to the world any important results." Now, it is not so much on account of Kew that I object to this sort of observation, as to its general spirit of antagonism to scientific research.

There is no doubt that the answer to the old question, which Gilbert might have asked three hundred years ago, "What is the cause of terrestrial magnetism?" is very jealously hidden from us by Nature. The earth probably contains much iron, but its great internal heat seems to forbid our imagining the iron to be magnetic. The assumption that a negative electric charge on the rotating earth will explain things requires such an enormous charge that this assumption has been discarded. There are annual and diurnal variations of a fairly regular kind; there are storms which have some relation to the Aurora Borealis, to sunspots and to earth currents. There are small sudden changes which seem to occur almost instantaneously all over the earth. Observations of these things may be useless from some points of view, but scientific men have been, and continue to be, willing to give up time and much money for this object. Utilitarians had to be cajoled through superstition to allow observations of the stars to be carried on in ancient times, and we have no such cajolery to offer. We simply say that it has been through this sort of useless-looking method of working that all our progress in science has come.

Engineers descended from men who sneered at Cavendish and Franklin and Volta and Oersted and Ohm and Faraday, are you who utilise the results of the work so sneered at, and pile up fortunes in consequence of it, are you the men to sneer at and ridicule the scientific work of the present day because it seems to you useless?

Tell us a better method of observation; give us better suggestions as to what these magnetic phenomena may mean; but the past record of scientific observation enables us to laugh at you when you say that magnetic observations may never give the world any important results. Was Nature ever so open and yet so closed about a secret as she is about this one of terrestrial magnetism? Was there ever one whose revelation promised so much? How very little we know of electricity and magnetism! Does the mere motion of the earth, taking no account of electric charges at all, cause it to be magnetic? Almost anything is on the cards. Surely I need not appeal to your cupidity, but it is quite possible that our knowledge of this secret may enable us to tap a tremendous store of Nature's energy.

Gentlemen, this is not a trades union, and it is not a society for the furtherance of pure scientific research, but it is a society of professional men who recognise the past services of scientific observers with gratitude and respect, and hope for greater ones in the future. And shall it be said of us that our gratitude is not greater than that of Judas, to whom indeed thirty pieces of silver was doubtless a large sum; that "we have given our hearts away a sordid boon"; and that as to our future hopes we are willing to sell our birthright for a mess of pottage?

THE NEW SCIENTIFIC LABORATORIES AT KING'S COLLEGE, LONDON.

ON the afternoon of October 30 the new scientific laboratories at King's College were opened by Lord Lister, in the presence of the Lord Mayor and a large and distinguished gathering of men of science. Lord Lister, after his introduction

by Dr. Robertson, the principal of the college, said the occasion marked an event of great importance in the higher education of the metropolis. The necessity of practical instruction to supplement mere lectures was now fully realised; and it was in order to satisfy this want in every particular that the new laboratories had been added to King's College. In many branches the college had long been well equipped for this purpose; the Wheatstone Museum in particular would bear witness to this; but the dissecting room, and the accommodation for the practical teaching of physiology had been very defective. But now all this had been remedied; the bacteriological laboratory and the geological department had also received many improvements; and, in short, it might safely be said that King's College was now fully abreast of the age in the opportunities it afforded for practical teaching in all departments.

The Lord Mayor proposed a vote of thanks to Lord Lister; and in seconding, the Hon. W. F. D. Smith, M.P., treasurer of the college, stated that the new buildings, together with their equipment, would, when completed, cost 20,000*l.*, and reminded his audience that only one-fifth of this sum had so far been subscribed.

Lord Lister having declared the laboratories open, they were inspected by those present.

The laboratories are the result of a comprehensive scheme of extension and improvement of the teaching accommodation of the college, resolved upon by the council in the summer of 1899, and now practically completed. The biological, architectural, anatomical, and mechanical departments have all benefited to a considerable extent by the new works, especially the departments first mentioned. The whole south wing of the college has been raised by an additional story, which includes the new geological, comparative anatomy and botanical departments, while the second story of the north wing, comprising the physiological and bacteriological departments, has been largely reconstructed, as has also the very fine room on the first floor now allotted to the architectural department. The reconstruction of the anatomical department and medical museum is also approximately complete, but the equipment is at present in progress.

The department of physiology comprises (1) a spacious central laboratory, seating over 100 students; the work tables are suited either for microscope work or for practical work in chemical physiology. There are in addition sixteen separate tables provided with shafting and all the necessary electrical apparatus for the study of experimental physiology, a branch of the science which is becoming every year of greater importance; (2) a large room for investigations in chemical physiology; (3) a spacious and well-fitted room for experimental physiology; (4) a dark room for photographic and galvanometer work; (5) a private workroom for the professor. These, with the necessary storerooms and accommodation for the laboratory attendants, make up a very complete suite of rooms.

In the anatomical department the dissecting room has been nearly doubled in size, and all the accessory rooms necessary in a well-equipped anatomical department are now provided. The section of the college museum which relates to pathology will also be housed in part of the old physiological rooms in the basement, and a new room has been built for the anatomical portion of the museum.

The department of bacteriology contains a practical classroom devoted to the technical education of post-graduate and other students from all parts of the world. Every student with his own hands goes through the whole practical course, and is further assisted by lectures and practical demonstrations. Several students have been especially trained with a view to investigating plague, cholera, yellow fever, madura and other tropical diseases, as well as the diseases of farm stock which are prevalent in our colonies and in foreign countries. In the technical laboratory, research work has been undertaken for the Board of Agriculture and for colonial Governments, while a number of workers have published researches on various bacteriological subjects. The new research room and library is used by advanced students and by the professor. A new feature is the bacteriological library of about 1000 volumes and pamphlets, lent by the professor for the use of the senior students. A lecture theatre has been built for the use of the bacteriological and physiological departments, and will accommodate about 200 students.

The general geological laboratory and lecture room will accommodate fifty students. The room is fitted both for lecturing